PITFALL TRAP SAMPLING OF TROPICAL CARABIDS (CARABIDAE : COLEOPTERA) — EVALUATION OF TRAPS, PRESERVATIVES AND SAMPLING FREQUENCY[1]

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Sampling ground beetles (Carabidae : Coleoptera) using pitfall traps was evaluated by comparing combinations of three trap types and five preservatives in a 3x5 factorial randomised complete block design over a period of four months for two sampling intervals namely, a week and a fortnight. Analysis based on the capture efficiencies of different treatment combinations resulted in the recommendation of glass jar pitfall traps (11x6 cm) with formalin (4%) or ethylene glycol (2%) as preservative, with a fortnightly sampling frequency. Preservative efficiency and trap recovery efficiency of traps in the two sampling experiments and the cost factor for using any one trap and preservative combinations of fortnightly sampling in the sampling programme are discussed.

INTRODUCTION

In recent ecological studies, carabids or ground beetles have received increasing attention owing to their frequent occurrence in all varieties of habitats and economic importance in agriculture (Saypulaeva 1986, Luff 1987). They also serve as pedobiological monitors, indicating habitat degradation (Luff *et al.* 1989). Hence, an ecological research study on carabids as potential indicators of environment and/or as economic bioagents, needs the development of a comprehensive, economical and environmentally suitable system of sampling.

Pitfall trapping sampling method has been found reliable to assess qualitative and quantitative species composition of carabids simultaneously in several habitats (Dennison and Hodkinson 1984). Pitfall traps were preferred to quadrats, as the latter has proven unserviceable (Loreau 1984). Many workers, therefore, used some form of pitfall trapping to monitor and assess populations of carabids (Mitchell 1963, Greenslade 1964, Sunderland 1975, Halsall and Wratten 1988). The effectiveness of pitfall traps reportedly depends on the material of construction, presence of a preservative and its chemical composition, number of traps and how often the traps are checked (Gryuntal 1982). So, as a prerequisite for sampling tropical carabids to study their species diversity, the present study attempts to evaluate the types of traps, preservatives and sampling frequency.

MATERIAL AND METHODS

Two experiments namely, weekly and fortnightly sampling experiments, each of Factorial Randomised Complete Block Design (FRCBD) with two replications each, were laid out simultaneously in two adjacent areas of an agroforest, each of 15,000 sq. m, to compare three trap types: glass jar (11x6 cm), aluminium tumbler (11x6.5 cm) and plastic tumbler (11x6 cm); and four preservatives: formalin (4%), ethylene glycol (2%), salt solution (20%) and detergent solution (2%). Traps without preservatives (empty traps) were also tested, hence there were 3x5 factorial combinations in

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two replications of each of the sampling experiments.

Traps were set in the soil with their position as per random allotment in FRCBD, with their opening flush with the soil surface. Measured quantities (50 ml) of preservatives were poured as directed by the sampling plan. Traps were checked once in three days to refill traps with preservatives, if required. Sampling was carried out for a period of four months with fifteen weekly and seven fortnightly collections.

The total catches of carabids, irrespective of species (measure of capture efficiency), for the three trap types with five preservatives over two replications were recorded for the two sampling programs. Also, the number of specimens that were well preserved (measure of preservative efficiency), number of times each preservative needed to be replenished during the sampling period (measure of cost and time efficiency), and number of traps that could be recovered for reuse at the end of the experimental period (measure of trap recovery efficiency) were made for the weekly and fortnightly experiments separately.

Statistical analysis

Weekly and fortnightly sampling experiments of FRCBD were analysed separately to answer three explicit questions: whether carabid catches indicate significant differences (a) among trap types (b) among the type of preservatives and (c) for interactive effects between trap types and preservatives.

Total number of carabids caught at the end of the experiment from two sampling periods was tested using student 't' test. The efficiency of preservatives in terms of number of carabid specimens recovered for further handling and efficiency of traps in terms of number of traps reusable between two sampling experiments were tested using chi square test. One way analysis of variance was used to detect differences among preservatives for frequency of replenishing.

Cost analysis for using any trap type with any preservative was done, taking into account the total number of traps used and total quantity of preservatives used, for the fortnightly sampling experiment.

Results

The analysis of variance (ANOVA) for carabid catches of weekly and fortnightly sampling experiments based on the FRCBD analysis are shown in Tables 1 and 2, respectively.

Table 1
ANOVA FOR TOTAL WEEKLY CATCHES OF CARABIDS

Source of variation	Degree of freedom	Sum of squares	Mean square	Computed 'F'
Replication	1	5.63	5.63	0.287^{NS}
Treatment	14	1908.47	136.32	6.943**
Trap (T)	(2)	1048.67	524.33	26.710**
Preservative (P)	(4)	452.13	113.03	5.757**
(T) x (P)	(8)	408.27	51.03	2.590^{NS}
Error	14	274.87	19.63	
Total	29	2188.97		

**: Significant at $P < 0.01$, ^{NS}: Not significant

Table 2
ANOVA FOR FORTNIGHTLY CATCHES OF CARABIDS

Source of variation	Degree of freedom	Sum of squares	Mean square	Computed 'F'
Replication	1	192.53	192.53	10.67**
Treatment	14	2542.20	181.59	10.07**
Trap (T)	(2)	680.00	340.00	18.86**
Preservative (P)	(4)	1300.00	325.00	18.03**
(T) x (P)	(8)	562.20	70.28	3.89*
Error	14	252.47	18.03	
Total	29	2987.20		

**: Significant at $P < 0.01$, *: Significant at $P < 0.05$

While the main treatment effects, namely traps and preservatives, showed significant differences in both sampling experiments, their interaction effect was significant only for the fortnightly

sampling experiment. Capture efficiency was significantly higher in glass trap and on par for all preservatives in both the experiments (Table 3). For the fortnightly sampling experiment, comparison of capture efficiencies among traps for preservatives (Table 4) showed on par capture when traps were left empty, and highest capture for all preservatives when used with glass jar. Comparison of capture efficiencies among preservatives for different trap types (Table 5) had shown no differences in carabid capture when any preservative was used with aluminium

TABLE 3
CAPTURE EFFICIENCIES* FOR TRAPS AND PRESERVATIVES OF WEEKLY AND FORTNIGHTLY SAMPLING EXPERIMENTS

Treatment comparison	Sampling experiment**	
	Weekly	Fortnightly
For traps		
Glass jar	28.2a	23.6a
Aluminium tumbler	17.1b	12.6b
Plastic tumbler	14.6c	13.4b
For preservatives		
Empty	12.3a	3.2a
Formalin	21.0b	21.7b
Ethylene glycol	22.7b	19.2b
Salt solution	22.7b	19.6b
Detergent solution	21.2b	19.0b

* Mean carabid catches over study period
** In a column, means followed by a common letter are not significantly different at $P < 0.05$

and plastic traps. Glass traps with formalin as preservative had the highest catch.

Comparison of carabid capture efficiencies between sampling experiments for trap types (Table 6) indicated significant differences corresponding to empty traps alone, with catches four times higher in weekly than those in fortnightly sampling experiment. Preservative efficiency varied between the experiments only for inorganic preservatives, namely salt and detergent solutions, with larger catches recorded

TABLE 4
COMPARATIVE EFFICIENCY OF TRAP TYPES WITH DIFFERENT PRESERVATIVES

Preservative**	Trap type		
	Glass jar	Aluminium tumbler	Plastic tumbler
Empty	2.5a	4.0a	3.0a
Formalin	36.0a	14.5c	15.5b
Ethylene glycol	22.5a	15.5c	19.5b
Salt solution	28.0a	14.5c	16.5b
Detergent solution	29.0a	14.5b	13.5c

* Mean carabid catches over study period
** In a row, means followed by a common letter are not significantly different at $P < 0.05$

TABLE 5
COMPARATIVE EFFICIENCY OF PRESERVATIVES WITH DIFFERENT TRAP TYPES

Preservative**	Trap type		
	Glass jar	Aluminium tumbler	Plastic tumbler
Empty	2.5d	4.0b	3.0b
Formalin	36.0a	14.5a	15.5a
Ethylene glycol	22.5c	15.5a	19.5a
Salt solution	28.0bc	14.5a	16.5a
Detergent solution	29.0b	14.5a	13.5a

* Mean carabid catches over study peirod
** In a column, means followed by a common letter are not significantly different at $P < 0.05$

in weekly sampling experiment (Table 7). Frequency of replenishment was the least in ethylene glycol and highest in formalin (Table 8). Recovery of plastic traps alone was significantly lower in weekly than in fortnightly sampling experiment (Table 9). Glass type traps used with any preservative (Table 10) in the fortnightly sampling experiment were least expensive.

DISCUSSION

Effect of type of traps and preservatives: Significantly higher capture efficiency for glass

TABLE 6
CAPTURE EFFICIENCIES* BETWEEN SAMPLING EXPERIMENTS FOR TRAPS

Trap type	Sampling experiment		Test of significance (t value)
	Weekly	Fortnightly	
Glass jar	31.75	28.88	1.099^{NS} (n=8)
Aluminium tumbler	17.63	15.00	1.132^{NS} (n=8)
Plastic tumbler	16.13	16.00	0.045^{NS} (n=8)
Empty trap	12.33	3.17	6.087^{NS} (n=8)

* Mean carabid captures over study period
NS: Not Significant, **: Significant at P<0.01

TABLE 7
PRESERVATIVE EFFICIENCIES BETWEEN SAMPLING EXPERIMENTS

Preservative	Sampling experiment		Test of significance (χ^2 value)
	Weekly	Fortnightly	
Formalin	92 (126)	89 (130)	0.942^{NS}
Ethylene glycol	88 (136)	86 (115)	0.259^{NS}
Salt solution	76 (136)	59 (118)	7.836**
Detergent solution	53 (127)	28 (116)	15.908**

* Percentage of carabids recovered for further handling

Figures within parentheses are the total number of carabids caught during the experiment

NS: Not Significant, **: Significant at P < 0.01

jar traps over aluminium and plastic traps from both the weekly and fortnightly sampling experiments revealed the superiority of glass jars for sampling carabids. The effectiveness of glass traps over polythene traps for carabid sampling has been reported by Gryuntal (1982). Although formalin has been reported to have an attractant effect (Luff 1968), the present study did not show difference in catches among preservatives. Irrespective of trap types, empty traps (any trap type without preservative) always registered lower carabid catches. Catches were lower in fortnightly than in weekly sampling experiment. Lower capture efficiency of empty traps can be explained, firstly by the general ability of smaller carabids to climb out of traps; secondly, by the devouring of smaller carabids by larger ones, and

TABLE 8
MEAN FREQUENCY OF REPLENISHMENT FOR PRESERVATIVES

Preservative	Mean frequency of replenishment*
Formalin	22.5b
Ethylene glycol	12.0a
Salt solution	17.0ab
Detergent solution	18.3b

* Means followed by a common letter are not significantly different at P < 0.05

TABLE 9
RECOVERY EFFICIENCY* FOR TRAPS BETWEEN SAMPLING EXPERIMENTS

Trap type	Sampling experiment		Test of significance (χ^2 value)
	Weekly	Fortnightly	
Glass jar	19	18	0.360^{NS}
Aluminium tumbler	17	16	0.173^{NS}
Plastic tumbler	10	16	3.956*

* Number of traps recovered at the end of experiment out of 25
NS: Not Significant, **: Significant at P < 0.05

TABLE 10
EXPENDITURE FOR TRAP-PRESERVATIVE COMBINATIONS IN FORNIGHTLY EXPERIMENT

Preservative	Trap type		
	Glass jar	Aluminium tumbler	Plastic tumbler
Formalin	34.01	83.90	38.11
Ethylene glycol	31.34	55.44	35.44
Salt solution	30.29	54.39	34.39
Detergent solution	30.27	54.37	34.37

* Figures denote the total expenditure (rupees) incurred during the sampling experiment taking into account trap and preservative life

thirdly, by the susceptibility of catches to predation by other groups such as lizards, rodents etc. The lesser efficiency of empty traps alone in fortnightly than in weekly sampling experiment suggests that increased time invigorates the above three factors. Luff (1975) found that glass traps could retain catches without the use of

preservatives better than metal and plastic traps. The present study, however, finds that preservatives are a must for trapping carabids in the tropics.

All preservatives, whether organic (formalin, ethylene glycol) or inorganic (salt, detergent solutions) showed higher effectiveness when used with glass jars. However, formalin used with glass jars recorded highest capture efficiency, indicating the supremacy of glass jars with formalin for carabid sampling. Greater impediment to insect movements on the glass surface, and the well known fixative effect of formalin appear to be the reasons for the greater efficiency of glass jars with formalin for sampling carabids.

Effectiveness of preservatives: While organic preservatives (formalin, ethylene glycol) had not differed in efficiency expressed as the number of carabid specimens recovered for further handling, the inorganic preservatives (salt, detergent solutions) had lesser catches of carabids. This might be due to the fixative properties of organic preservatives. It was observed that a larger number of specimens separated out had heads detached from their bodies and an offensive smell, hampering the separation process, from inorganic preservatives in the fortnightly sampling experiment. This indicates that biodegradation sets in at traps with salt or detergent solutions with a long sampling interval, and their unsuitability as preservatives for more than a week's sampling frequency.

The time factor analysis on preservatives based on mean frequency of replenishing shows that ethylene glycol and salt solution required more frequent replenishment than formalin and detergent solution. This is due to the differential evaporation rate of preservatives tested. Adis (1979) has reported lower evaporation rate of ethylene glycol in pitfall traps.

Recovery efficiency of traps: Recovery of a smaller number of plastic pitfall traps in weekly sampling experiment than in the fortnightly sampling experiment is attributed to the lesser resistance offered by the traps to frequent replacements. With glass jar and aluminium tumbler traps, the loss of traps was negligible in both experiments.

Sampling cost for trap and preservative combinations: Expenditure incurred for the fortnightly sampling experiment alone was calculated, as the interaction effect of traps and preservatives was significant for that sampling frequency. It was seen that, for any preservative used with glass jar, the costs are the least and with aluminium trap the highest.

With the salt and detergent solutions proving unsuitable among preservatives and glass jar superior among trap types, cost benefit analysis is valid only between the use of formalin and ethylene glycol with glass jar traps. The difference was small (Rs. 34 for glass jar with formalin, and Rs. 31 for glass jar with ethylene glycol) suggesting that choice can depend on availability.

Overall perspective of the developed sampling programme: On the basis of this study the use of glass jar (11x6 cm) traps with formalin (4%) or ethylene glycol (2%) as preservative with a sampling frequency of a fortnight is recommended to be cost effective for studies of distributional limits and to measure their dynamic relations with the environment.

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